1.0 INTRODUCTION:

Mechanical evaluation of weldment is done to test the suitability of the joint and fitness for the purpose to satisfactorily meet the intended applications. The tests include – Tension test, Impact test, Hardness test, Bend test, etc.

2.0 TENSILE TESTING:

A tensile test, also known as tension test, is probably the most fundamental type of mechanical test performed on material. Tensile tests are simple, relatively inexpensive, and fully standardized. Schematic appearance of tensile testing machine is shown in figure-1.

Figure-1: Photograph of tensile test machine.

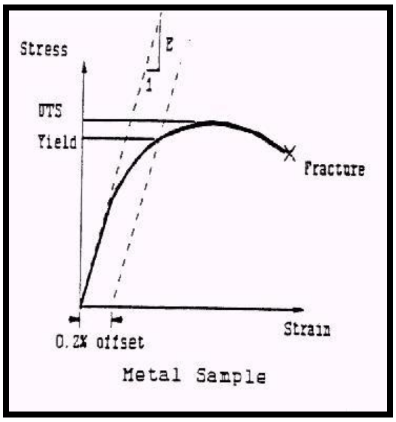

Figure-2: Sketch of Stress-Strain diagram of a tension test.

Standard samples are prepared as per the requirement of the code or specification and are loaded in the machine. The sample is loaded in tension and the changes in the material behaviour are noted with the applied tensile load. Pull is continued till the sample breaks. A typical curve thus is formed known as Stress-Strain diagram (figure-2).

For most tensile testing of materials, the initial portion of the test, the relationship between the applied force, or load, and the elongation the specimen exhibits is linear. In this linear region, the line obeys the relationship defined as "Hooke's Law" where the ratio of stress (σ) to strain (ε) is a constant. **Stress** is defined as “Load/Cross-sectional area” and **Strain** is defined as “Change in length/ Original length”.

$$\frac{\sigma}{\varepsilon} = E$$

E is the slope of the line in this region where stress (σ) is proportional to strain (ε) and is called the **Modulus of Elasticity** or **Young's Modulus**. Till this stage no permanent deformation occurs and material comes back to its original state if the load is released. This zone of curve is called **Elastic zone**.

With further enhancement of load the material starts forming permanent deformation. The particular stress beyond which the permanent deformation starts is called **Yield strength (YS)**. Since that particular point is very difficult to identify in the Stress-Strain diagram, an off-set method (ASTM E8: Standard methods for Tension Testing of Metallic Materials) wherein the stress corresponding to the 0.2% strain is defined as **Yield strength or 0.2% Proof stress** (figure-2). With further increase in load, the material fails at a particular stress. The maximum load thus on the Stress-Strain curve is defined as **Ultimate tensile strength (UTS)**.

There are many standard types of tensile test specimens. One such specimen is schematically shown in figure-3. The standard test piece is an accurately machined specimen. Overall length is not a critical item, but the diameter (d) and gauge length (L) are critical. Generally the gauge length is four times the diameter of the specimen (L=4d). The physical change in shape of the tensile test is shown in figure-4. The difference in the gauge length between before & after the test measures the **Elongation** of the metal.

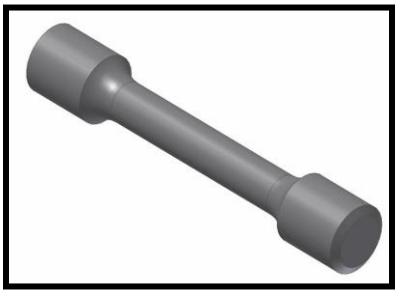

Figure-3: Schematic diagram of a tensile test piece.

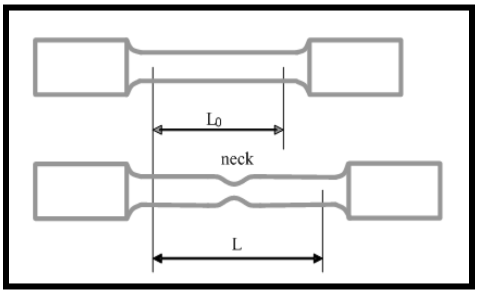

Figure-4: Representation of a tensile test piece before & after the test

$$\text{Elongation (\%)} = \frac{(L - L_o)*100}{L_o}$$

In connection to weld metal evaluation through tension test, two types of tests are done. First one is all-weld metal test and second type is transverse tensile taken across the weld metal.

The cross-section of the former is round whereas for the transverse tensile test piece it is rectangular. All-weld metal tension test is done to evaluate the weld metal strength & elongation but transverse tensile test is performed to study the strength as well as failure location (weld/parent metal) in a butt-weld assembly. Figure-5 & figure-6 show the location of test pieces in an all-weld & a butt-weld configuration.

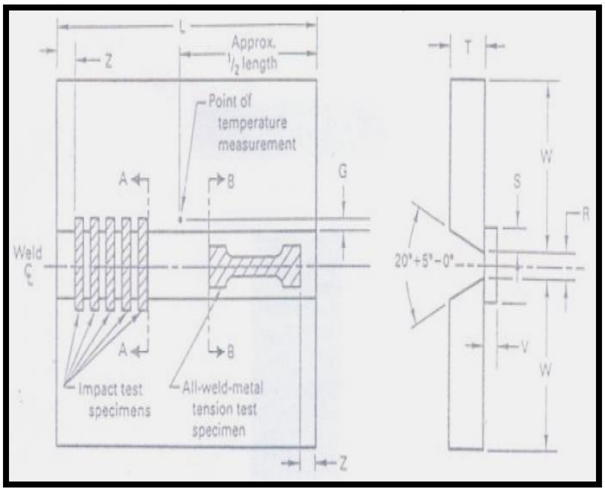

Figure-5: Schematic location of test pieces in an all-weld assembly.

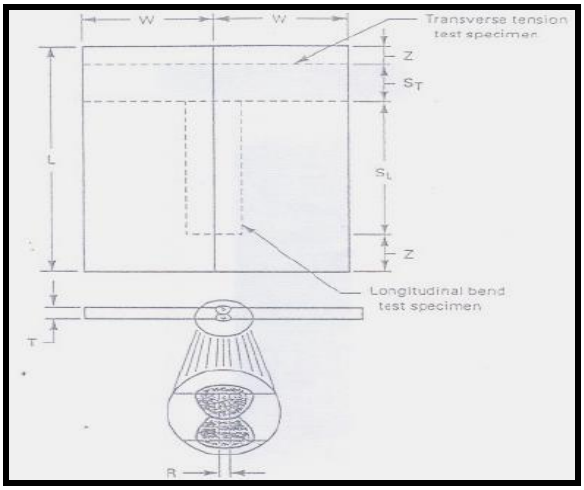

Figure-6: Schematic location of test pieces in a butt-weld assembly.

3.0 CHARPY IMPACT TESTING:

The **Charpy impact test**, also known as the **Charpy V-notch test**, was developed in 1905 by the French scientist Georges Charpy. It was pivotal in understanding the fracture problems of ships during the World War-II. Today it is used in many industries for testing building and construction materials used in the construction of pressure vessels, bridges, structures, etc.

The Charpy test (figure-7) measures the energy absorbed by a standard notched specimen while breaking under an impact load. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition. It is used as an economical quality control method to determine the notch sensitivity and relative impact toughness of engineering materials. The test data also facilitate to determine the minimum service temperature for a material.

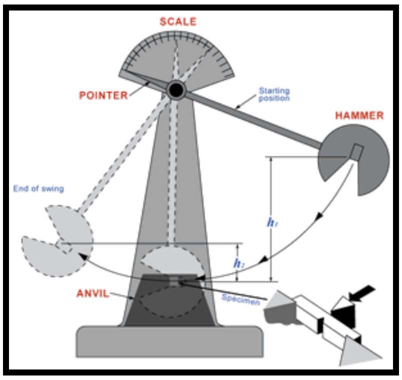

Figure-7: Schematic representation of Charpy Impact testing machine

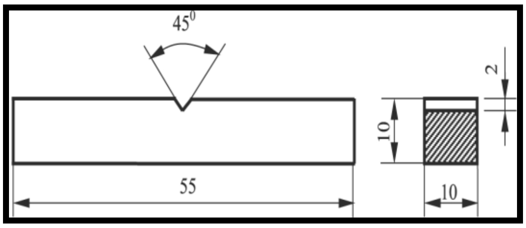

Figure-8: Dimensions of a standard Charpy Impact test specimen.

The standard Charpy Test specimen (figure-8) consist of a bar of metal 55x10x10mm having a notch machined across one of the larger dimensions. **V-notch:** 2mm deep, with 45° angle and 0.25mm radius along the base. The apparatus consists of a pendulum swinging at a notched sample of material. The energy transferred to the material can be calculated by comparing the difference in the height of the hammer before and after a big fracture. The details of the test and equipment used are described in ASTM E23, "Standard methods for Notched Bar Impact Testing of Metallic Materials".

The notch location of test piece is very critical. For weld metal it is taken along the centre-line of the weld (figure-9). Sometimes for the evaluation of fusion line and HAZ behaviour in a butt-weld assembly, notch is done along the fusion line and 2mm away from the fusion line respectively (figure-10).

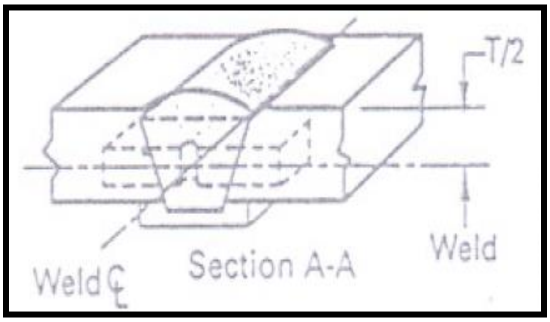

Figure-9: Schematic location of impact test piece in AWS all-weld assembly.

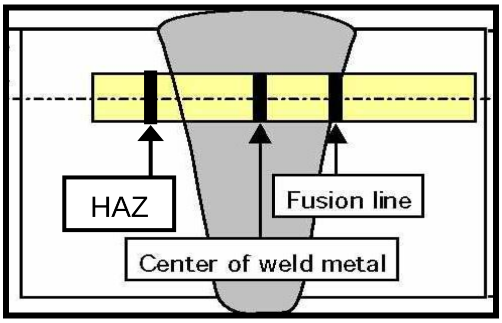

Figure-10: Schematic location of notch in a butt-weld assembly.

4.0 HARDNESS TESTING:

Hardness test implies the resistance offered by a material against indentation. Among the various test method available, the most common method followed in the industry are Brinell and Rockwell hardness tests.

4.1 Brinell hardness test – Widely used on castings and forgings, the Brinell hardness test machine (figure-11) applies a predetermined test force (F) to a carbide ball of fixed diameter (D) which is held for a predetermined time and then removed. The diameter (d) of the indentation width is measured twice - usually at right angles to each other and averaged. A formula (figure-12) is then used to convert the averaged measurements to a Brinell hardness number.

Figure-11: Photograph of Brinell hardness test machine.

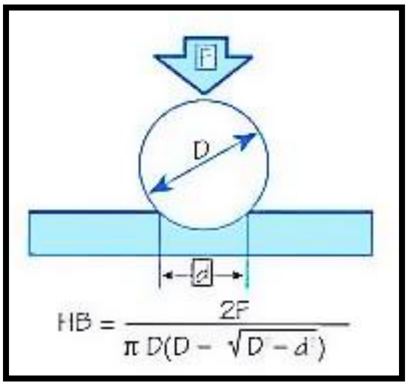

Figure-12: Schematic sketch of indentation in Brinell machine

4.2 Rockwell hardness test – This test operates by measuring the differential depth of a permanent deformation caused by the application and removal of minor load and major load. Various penetrator and load combinations are used to adapt to materials of varying hardness and thickness. The penetrators include a cone-shaped diamond and hard steel balls 1/16" to ½" diameter.

The standard Rockwell test (figure-13) uses a minor load of 10 kg to seat the penetrator firmly in the surface of the specimen. Then the depth gage is zeroed and the major load is applied. On release of the load, Rockwell hardness numbers are measured from the indentor location in the dial (the depth of penetration is calibrated with the dial gauge). Major loads for the Rockwell test are 60, 100 and 150 kg for A, B & C scales respectively.

Figure-13: Photograph of Rockwell hardness test machine.

The Rockwell hardness tester also measures the resistance to penetration like Brinell test, but in the Rockwell case, the depth of the impression is measured rather than the diametric area. With the Rockwell tester, the hardness is indicated directly on the scale attached to the machine. This dial like scale is really a depth gauge, graduated in special units. The Rockwell hardness test is the most used and versatile of the hardness tests.

5.0 BEND TESTING:

5.1 Free-Bend Test – This test is designed to measure the ductility of the weld deposit and the heat-affected area adjacent to the weld. Also it is used to determine the percentage of elongation of the weld metal.

The first step in preparing a welded specimen for the free-bend test is to machine the welded reinforcement crown flush with the surface of the test plate. When the weld area of a test plate is machined, as is the case of the guided-bend as well as in the free-bend test, perform the machining operation in the opposite direction that the weld was deposited.

The next step in the free-bend test is to scribe two lines on the face of the filler deposit. Locate these lines 1/16 inch from each edge of the weld metal, as shown in figure-14, view B. Measure the distance, in inches, between the lines to the nearest 0.01 inch and let the resulting measurement equal (x). Then bend the ends of the test specimen until each leg forms an angle of 30 degrees to the original centerline. With the scribed lines on the outside and the piece placed so all the bending occurs in the weld, bend the test piece by using a hydraulic press or similar machine.

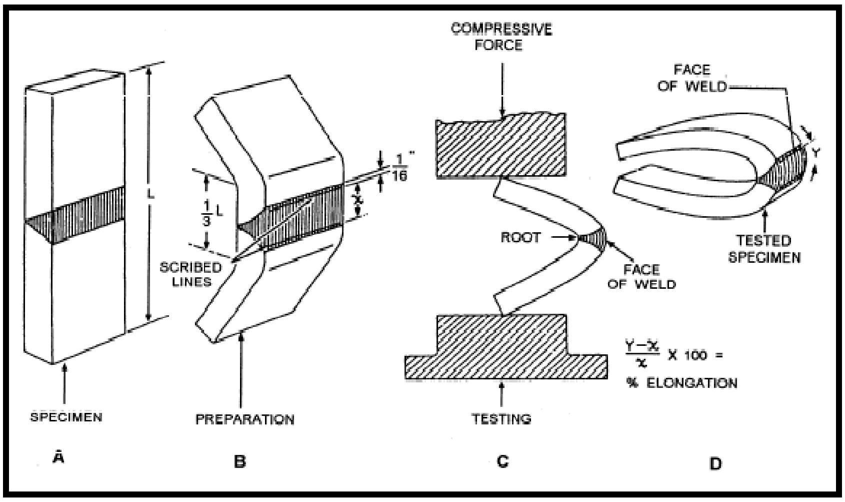

Figure-14: Schematic representation of the free-bend test.

When the proper precautions are taken, a blacksmith's forging press or hammer can be used to complete the bending operation. After completing the test, measure the distance between the scribed lines and call that measurement (y). The percentage of elongation is then determined by the formula:

$$\boxed{\frac{Y-X}{X} \times 100 = \%\ \text{elongation}}$$

Requirement for satisfactory test criteria is minimum elongation of 15 percent and no cracks greater than 1/16 inch on the face of the weld.

<u>5.2 Guided-Bend Test</u> – This test is done to determine the quality of weld metal at the face and root of a welded joint. This test is made in a specially designed jig. The location of test pieces is shown in figure-10 and the jigs of guided bend test are shown in figure-15 & 16.

The test specimen is placed across the supports of the die. A plunger, operated from above by hydraulic pressure, forces the specimen into the die. To fulfill the requirements of this test, you must bend the specimen 180 degrees—the capacity of the jig. No cracks should appear on the surface greater than 1/8 inch. The face-bend tests are made in this jig with the face of the weld in tension (outside while root-bend tests are made with the root of the weld in tension (outside), as shown in figure-17.

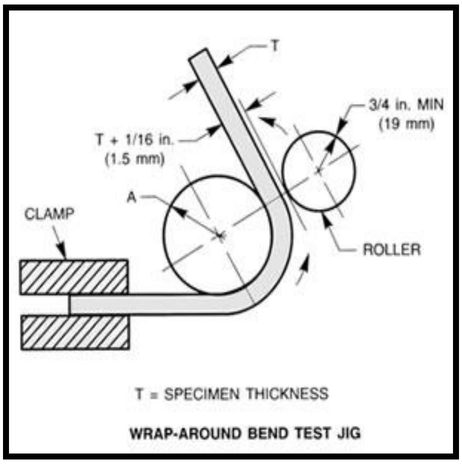

Figure-15: Photograph of wrap-around guided bend test jig.

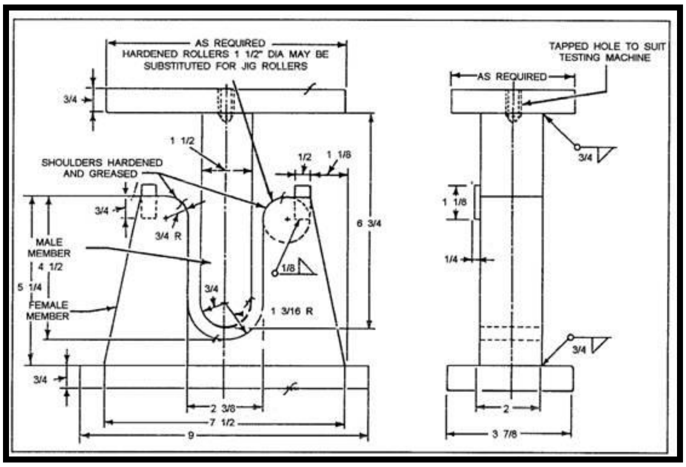

Figure-16: Photograph of mandrel type guided bend test jig.

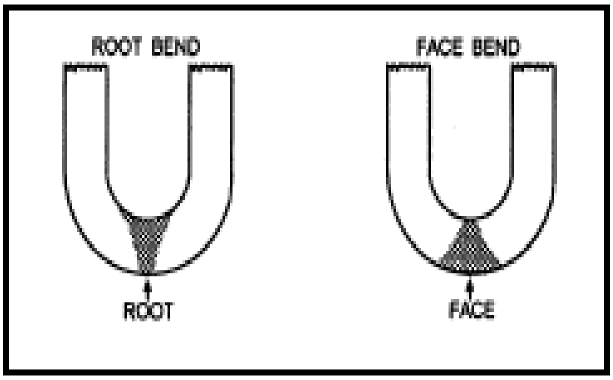

Figure-17: Photograph of root & face bend specimens.